AFIT/GCA/LAS/93S-8



# A COST MODEL FOR USAF ACQUISITION OF COMMERCIAL AIRCRAFT FOR SERVICE IN THE SPECIAL AIR MISSION FLEET

THESIS

C. Grant McVicker III, Captain, USAF
Michael T. Roche, Captain, USAF

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THESIS

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Acquisition Management of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degrees of
Master of Science in Cost Analysis and
Master of Science in Systems Management

C. Grant McVicker III, B.S., M.B.A.
Captain, USAF

Michael T. Roche, B.S.
Captain, USAF

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## Preface

The Commercial Aircraft Integrated Cost Estimating Tools (CAICET) Model was developed to provide the cost estimator a user-friendly automated model for estimating the cost of procuring and modifying commercial, off-the-shelf, aircraft for introduction into the Air Force Special Air Mission Fleet. This model provides the analyst the quick reaction capability to estimate commercial buys in a standardized, logical format.

In developing this model we have had a great deal of help from others. We are deeply indebted to Michael Copeland (TASC) for his programming expertise and our plethora of advisors, Major Wendell Simpson, Jeff Daneman, Capt Tom Tracht, and Steve Malashevitz, for their patience and assistance. We also wish to thank the many acquisition specialists in the Directorate of Transports of the Aircraft System Program Office. Most of all, we wish to thank our wives, Gayle and Lilly, and children, Katie, Matthew, and Ann Margaret for their love and understanding on those many nights we were tied to the computer with work.

C. Grant McVicker III

Michael T. Roche

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## Abstract

The purpose of this research was to develop a cost estimating model which would allow cost estimators the ability to quickly and accurately estimate the acquisition of Air Force Special Air Mission fleet aircraft. The literature review revealed studies, government contracts, and trade publications which served as source data. This information was supplemented by interviews with acquisition specialists and contractors and incorporated into a database. Several estimating techniques were created and used to estimate the various cost elements. The Commercial Aircraft Integrated Cost Estimating Tools (CAICET) Model was then developed to incorporate the estimating techniques with the database. This was accomplished by integrating dialog boxes to access the information and estimate the program acquisition.

The CAICET Model provides the analyst with the ability to estimate an acquisition program based on a few specific parameters concerning the missionization of the aircraft. These parameters include interior configuration, avionics, mission communications, and self-sufficiency items. Once this information is input, the CAICET Model provides the analyst with a real-time estimate in standard AF Form 1537 format.

# A COST MODEL FOR USAF ACQUISITION OF COMMERCIAL AIRCRAFT FOR SERVICE IN THE SPECIAL AIR MISSION FLEET

## I. Introduction

### General Issue

The Department of Defense (DoD) specifies that a full range of alternatives must be considered prior to deciding to initiate a new acquisition program. In support of this mandate, mission needs are first assessed to determine if they can be satisfied by nonmaterial solutions, such as changes in doctrine, operational concepts, tactics, training, or organization. If a nonmaterial solution will not fulfill the mission need then a hierarchy of potential material alternatives must be considered. The first material solution is the use or modification of an existing US military system. The second material alternative is to consider the use or modification of an existing commercially developed system that fosters a non-developmental acquisition strategy. The directive states that the acquisition strategies and program plans should make maximum practical use of commercial and other non-developmental items (1:1-2,3).

According to a December 1992 article in Leading Edge, the Department of Defense is paying increased attention to

non-developmental item (NDI) acquisition as a cost-effective alternative to buying items tailor-made for the military. The article states that the push to use commercial items has been accelerated by the collapse of a credible military threat and the shift to a global economy which has bolstered the need for accelerating NDI. In addition, as the military downsizes, the administration and Congress have increased expectations that less will be spent on military research and development (2:20). This places an even greater pressure on the military to look for NDI solutions to meet mission needs.

Commercial-off-the-shelf (COTS) is considered a subset of NDI. A simple definition of COTS is "an item of commercial design for commercial use" (3). The desirability of buying commercially available items has intuitive appeal. Competition often drives manufacturers to be cost effective and offer products of the highest quality, latest technology, and fairest value. The Air Force understands these benefits stating, in AFR 57-1, that the use of NDI is encouraged. NDI systems, subsystems, components, and technologies enhance the economy of DoD resources by minimizing R&D efforts that would require additional time and monies. Other benefits include economies of scale, proven and mature capabilities, and greater use of standardized, common systems and equipment (4:27). The potential benefits of exploring commercial

acquisition avenues have also been recognized by the Aeronautical Systems Center (ASC):

> In a period of dwindling defense budgets and public attention on the relationship between acquisition lead time and weapons systems cost estimates, the acquisition of commercial products becomes increasingly attractive. (3:1)

## Specific Issue

The Air Force Special Air Mission (SAM) Fleet provides worldwide air transportation for the President and Vice President of the United States, Cabinet members, Congressmen, and other high ranking dignitaries of the United States and foreign governments. The high visibility associated with transporting these VIPs elicits vigilant investigation of the SAM fleet and in particular the acquisition of these aircraft. This intensified scrutiny places increased demands on the acquisition specialists to provide detailed, credible, real-time cost estimates. This scrutiny is often in the form of "What-If" exercises which require an immediate response and necessitates that the analysts have the tools available to estimate SAM fleet aircraft in a timely, structured, and reliable manner.

## Research Objective

The above stated situation coupled with the downsizing currently underway in the Air Force has left the cost

community in need of a user-friendly automated cost estimating model tailored to the acquisition of commercial aircraft. The purpose of this thesis is to research and create a Commercial Aircraft Integrated Cost Estimating Tools (CAICET) Model for estimating the procurement and modification of commercially available, off-the-shelf, aircraft for introduction into the SAM fleet. This model will be designed to provide the analyst the quick reaction capability to estimate commercial aircraft procurements in a structured, logical format. CAICET will contain Cost Estimating Relationships (CERs), Factors, and Look-up tables, as well as source references, historical data, and expert opinions into the nuances of estimating these types of programs. The model will also provide the estimator the flexibility to retrieve and extract data from a database for use in creating other estimating relationships.

**Scope and Limitations**

The CAICET Model is solely for estimating the acquisition cost associated with the procurement and modification of commercial aircraft for military missions. Although CAICET does not specifically address Research and Development costs, the model does allow for the estimating of these costs. Operations and Support costs are not addressed in this model.

The VC-X program, which is designated to replace the VC-137 fleet, has been identified as the next acquisition for the SAM fleet. This research will be centered around the requirements set forth in the VC-X program. However, this research is not limited in its application to this specific program.

An extensive portion of the CAICET Model relies on catalog prices in estimating cost elements. Therefore, the user must periodically update the database.

**Summary**

The Cost Estimator's Reference Manual states that the purpose of cost analysis is to provide management with data for use in decision making (6). The purpose of this research is to develop the CAICET Model which will allow cost estimators the ability to quickly and accurately estimate the acquisition of SAM aircraft for use by the decision makers. This model will also provide the estimators an automated method for performing "What-If" analysis. In a period of decreasing budgets and increasing emphasis on getting more for less, it is imperative that the decision makers have the most current and accurate cost data available on demand. The CAICET Model will provide the analyst a systematic and standardized approach for fulfilling this mandate.

# II. Literature Review

## Introduction

This literature review investigates United States Air Force (USAF) acquisition of executive aircraft and serves as a building block for the thesis to develop a cost model for USAF acquisition of commercial aircraft for service in the Special Air Mission (SAM) fleet. The SAM fleet provides worldwide air transportation for US government executives and other high ranking dignitaries, including those of foreign nations. This review surveys literature on the requirements and direction for the SAM fleet, examines current studies on this subject, identifies sources of cost estimating techniques, and discusses the use and applications of the cost workstation.

## Special Air Mission Requirements and Direction

The SAM fleet, part of the 89th Military Airlift Wing (MAW) at Andrews Air Force Base, MD, provides worldwide air transportation for US government executives and other high ranking dignitaries, including those of foreign nations. World events may, at any time, require the SAM fleet to be able to simultaneously transport the nation's leaders on

different diplomatic missions. Communications and physical security are integral to the mission since principals and their staffs must conduct business en route. Based on the HQ MAC Statement of Need and draft Operational Requirements Document for the VC-X, in conjunction with personal interviews with personnel from the Directorate of Transports Program Office (the ASC program office responsible for the acquisition of commercial aircraft for the SAM fleet) the following requirements should be included in the cost model: executive interior; avionics; mission communication system; self-sufficiency through the use of self-contained airstairs, baggage loader, security system, and auxiliary power unit; and a self defense system (7). The Defense Information System Agency's Executive Fleet Airborne Communications Architecture provides the requirements for the Mission Communication System (8).

The need for replacement of the aircraft currently serving in the SAM fleet was identified through Congressional inquiries which resulted in the 89th MAW Master Plan. This plan highlighted the inability of the VC-137 fleet to meet current noise and air pollution regulations, the high fuel consumption of the VC-137s, and technical limitations of the aging airframes. Replacement of the VC-137 fleet was stated as the number one priority of the Master Plan. This plan was approved by the Secretary of the Air Force on 26 February 1990 (9).

The Headquarters Military Airlift Command (HQ MAC) Statement of Operational Need (SON) of 1 May 91 addresses the limitations of the VC-137 aircraft: dependence on ground support aircraft, high cost of replacement parts, inability to meet noise restrictions and modern air pollution regulations, high fuel consumption, and the technological limitations of the aging aircraft. The VC-137 fleet, three B models averaging 34 years of age and four C models averaging 24 years of age, is becoming obsolete (10). Several key parts are no longer manufactured and must be specially machined. Finally, the Federal Aviation Administration (FAA) Stage 3 noise reduction requirements will preclude the fleet from operating into major airports by the year 2000 (11:6).

**Current Studies**

The VC-X Requirements Trade-Off Study (ASD/SDC, 16 Mar 92) evaluates a wide range of aircraft which can, to varying degrees, fulfill the mission as specified in the paragraphs above. The evaluations and findings of this analysis will be beneficial to the thesis effort as they provide insight to the requirements of the decision makers and hence the requirements of the cost model.

The VC-X Requirements Trade-Off Study provides several lists of discriminators to be separately estimated in the thesis model. Performance discriminators which affect the

mission include range, cabin utility, and cargo utility. These define the capability of the aircraft to take passengers and equipment a given distance in the minimum time. Range affects the number of stops required on a mission; cabin utility refers to the ability to accommodate an executive interior with a state room, distinguished visitor compartment, work areas, and general seating; and cargo utility represents the capability of an aircraft to accommodate baggage loaders, water tanks, mission support kits, consumables, freezers, and passenger and crew baggage. Other discriminators include time to climb to a designated flight level, noise and pollution compliance, and electrical power. These discriminators can be used to ascertain the aircraft's flexibility during the mission. As stated previously, FAA Stage 3 noise requirements must be met. Finally, electrical power is used as a measure of the aircraft's inherent self-sufficiency.

The Cost Estimators Guide to Commercial Aircraft contains a database which may be used in the estimating of cost elements for commercial aircraft (12). This study provides the analyst data on several military purchases of commercial aircraft and analysis of data to determine if a relationship exists between cost elements and physical and performance characteristics.

**Cost Estimating Techniques**

The sources of cost estimating techniques include: The Air Force Systems Command (AFSC) Cost Estimating Handbook, The AFSC Financial Management Handbook, Cost Analysis Journal, and the Armed Forces Comptroller. These handbooks and journals provide a variety of estimating methods such as: the grass-roots approach; analogies; linear, quadratic, and parametric models; and learning curves. Cost estimating relationships, extrapolated from similar past acquisition experience, and complexity factors, based on technical engineering studies, can be applied to the basis of the estimate to determine various candidate aircraft costs.

Further guidance on cost estimating can be found in: Office of Management and Budget Circular A-109, Major Systems Acquisitions; DoD Instruction 5000.2, Defense Acquisition Management Policies and Procedures; DoD Manual 5000.2-M, Defense Acquisition Management Documentation and Reports; and AF Regulation 57-1, Air Force Mission Needs and Operational Requirements Process.

**Software**

The Cost Workstation has been widely recognized in ASC and was recommended as a good starting point by the intended user. After an examination of the Cost Workstation, the thesis team chose to pattern CAICET after the Cost Workstation for the following reasons:

1. The Cost Workstation provides the cost analyst with an integrated, automated tool for performing cost estimating tasks and the documentation of those tasks (13: 3-2)
2. The user currently uses Windows 3.1, Excel 4.0, PowerPoint, and Word for Windows environment
3. The architecture of the Cost Workstation uses the above software
4. This eliminates the need for the user to learn a new software language

The cost workstation was developed to provide the analyst with the same environment as Excel. This includes the ability to modify any of the defaults that are contained in the Cost Workstation. This same flexibility has been built into the CAICET Model.

**Conclusion**

The first step in the literature review was to survey the requirements and direction of the SAM fleet. After reviewing this literature we determined that there was an ongoing need for estimating the cost of acquiring new aircraft for introduction into the SAM fleet.

The next step was to examine current studies concerning military acquisitions of commercial aircraft. The most recent literature on this subject was the VC-X Requirements Trade-Off Study. This study outlined a wide range of aircraft options that could fulfill the requirements of a

SAM type aircraft. The study also included cost estimates for these aircraft. The Cost Estimators Guide to Commercial Aircraft provides the analyst data on several military purchases of commercial aircraft and analysis of the data to determine if a relationship exists between cost elements and physical and performance characteristics. Although both of these documents serve as sources of data for the estimating of cost elements, neither provide the analyst an automated and integrated tool for estimating commercial aircraft using a systematic and standardized method.

Current estimating techniques were then surveyed for their application in estimating these types of programs. These techniques will be incorporated in the CAICET Model.

The final step of this literature review was to determine the software application in which to develop the model. The decision to pattern the CAICET Model after the ASC Cost Workstation was based on the user's desire that the model be developed in Excel.

# III. Methodology

## Introduction

This chapter describes the methodology used to accomplish the research objective stated in Chapter 1. It outlines the general methods applied by the researchers in the development of the CAICET Model. The first step in the research process was to develop a Work Breakdown Structure tailored for SAM fleet aircraft. The next step was data collection, which was followed by the creation of a database. Finally, cost estimating methods were tailored for the WBS elements.

## Work Breakdown Structure (WBS) Development

The WBS was based on guidance provided in MIL-STD-881B. This general WBS was then customized to commercial aircraft acquisitions through interviews with Aircraft SPO personnel (ASC/SDC). This program office is tasked with the acquisition of commercial aircraft for military use and is considered the "Center of Excellence" for this type of acquisition.

### Data Collection

An extensive search of available publications, catalogs, and government cost data was conducted. The documents reviewed include: AVMARK, Jane's All the World's Aircraft, Business and Commercial Aviation, Air Force Magazine, Air Force One documentation (McDonnell Douglas and Boeing BAFOs), VC-X Requirements Trade-Off Study, Cost Estimators Guide to Commercial Aircraft, Defense Information Systems Agency's Executive Fleet Airborne Communications Architecture, contractor Rough Orders of Magnitude (ROMs) and other commercial program cost data. This data was supplemented by interviews with aircraft manufacturers and ASC acquisition specialists.

### Database Creation

Once the data is collected, it is archived in an Excel spreadsheet. This allows CAICET users ready access to the information for use in estimating cost elements. From this database, the users are capable of manipulating the data to create their own CERs and factors. This manipulation is made possible through the use of macros embedded within the Excel software. Excel reference manuals were used in creating the database.

**Estimating Methods**

A cost estimating relationship (CER) relates cost as the dependent variable to one or more independent variables. It is expressed as a mathematical equation and once established is fairly simple to apply (14: 3-22). One type of CER is a regression equation. The basic concept of a regression model is that there is a tendency of the dependent variable Y to vary with the independent variable X in a systematic fashion. This implies that there is a distribution centered around the regression line and that every point on the line is a mean (15:26-54). For this CER, it is assumed that the normal error regression model is applicable. The first step in CER development is to identify the independent variables that will logically drive cost. Once these variables are identified the next step is to determine whether these variables provide significant correlation. There are several software statistical packages available which provide the associated statistics to a given regression equation. CERs that were created for the CAICET Model were developed in Excel.

An example of the use of a regression equation is the estimation of the cost of an executive interior (dependent variable) based on the interior square footage of the aircraft (independent variable). The user is provided cost data of executive interiors from commercial acquisition programs and is able to construct a CER using this data.

Certain WBS elements are estimated based on currently available catalog or list prices. In these cases, current trade publications and contractor ROMs are used.

Factors provide a means for the estimator to capture historical experience of similar programs to estimate future costs. Factors are used to estimate the elements of Engineering Change Orders, Systems Engineering/Program Management, System Test & Evaluation, Data, Peculiar Support Equipment, Training and Initial Spares. Factors are created using historical cost data of previous aircraft programs. This is accomplished by dividing the actual cost for the cost element being addressed by the actual air vehicle cost of the program. For example, for the Air Force One program we will take the cost of Data and divide it by the cost of the total air vehicle. This results in a cost factor for Air Force One data. This process is followed for each aircraft in the database. The next step is to weigh these factors based on complexity, using regression techniques. The complexity factors are derived and assigned to each aircraft in the database based on interviews with Aircraft System SPO specialists (7).

**Conclusion**

Various methods are employed in the creation of the CAICET Model. These methods include interviewing acquisition specialists, reviewing source documentation, and

applying regression techniques. Chapter 4 is the culmination of our research efforts. This chapter serves as the user's manual to the CAICET Model. This manual can serve the user as a source document on the estimating process and available methods. It also provides procedures for using the CAICET Model, a guide in estimating commercial aircraft, and an example of how to estimate using the CAICET Model.

# IV. CAICET Model

## Introduction to CAICET

The Commercial Aircraft Integrated Cost Estimating Toolss (CAICET) Model was developed to provide the cost estimator a user-friendly automated model for estimating the cost of procuring and modifying commercial, off-the-shelf, aircraft for introduction into the Special Air Mission (SAM) Fleet. This model provides the analyst the quick reaction capability to estimate commercial buys in a standardized, logical format. CAICET integrates Cost Estimating Relationships (CERs), Factors, and Catalog Price Modules, and provides source references, historical data, and expert opinions into the nuances of estimating these types of programs. The model also provides the estimator the flexibility to retrieve and extract data from the database for use in creating other estimating relationships. Appendix C provides the user with an example of an estimating scenario and the required inputs for CAICET.

CAICET was designed to operate within the Windows 3.1, Excel 4.0, PowerPoint, and Word for Windows environment. This was done so that the user would not have to learn a new software package to be able to operate CAICET. This manual

was written to be a stand-alone document and provides the user with all of the information necessary for operating CAICET.

There are primarily two files with which the user will interface. The first file, SAM.DEF, provides the proposed Work Breakdown Structure (WBS) and associated estimating methodologies for each WBS element. The second file, MRMCV.XLS, is the database. This file contains all of the data used for estimating each WBS element contained in the SAM.DEF file. The remaining files within CAICET are comprised of Macros for the operation of the model.

The first section of this manual provides an overview of the CAICET Model and information on the installation of the CAICET Model. The second section walks the analyst through each block or module represented in Chart 1 and provides a general overview and a description of the required procedures of each step. The third section of this manual serves as a guide for the analyst in estimating commercial aircraft for introduction into the SAM fleet. This section proposes a WBS structure tailored to commercial programs, and methodologies and data to estimate each WBS element. The authors previously served as Cost Estimators for the VC-X program and were the principle contributors to the cost estimating sections of the VC-X Requirements Trade-Off Study. The insight they gained by participating in this study is incorporated in this manual in the form of

unofficial guidance for estimating. Appendix C provides an example of an actual estimate estimated using CAICET.

**Installing CAICET**

The following steps should be followed when installing CAICET to the hard drive:

1. Create a CAICET subdirectory:
   Open File Manager
   Select File
   Select Create Directory
   Name: C:\CAICET

2. Copy CAICET Files (from disk) to CAICET subdirectory
   Select File Manager
   Select File
   Select Copy
   From: B:*.* or appropriate disk drive
   To: C:\CAICET

3. Create a Program Group
   Select File
   Select New
   Select Program
   Select Program Group
   Description: Models

4. Create CAICET Icon
   Select File
   Select New
   Select Program
   Select Item
   Description: CAICET
   Command Line: GLOBAL1.XLA
   Working Directory: C:\CAICET
   Select Icon of your choice

**Getting Started with the CAICET Model**

The CAICET Model is opened by selecting the CAICET Icon. The model is comprised of eight modules: WBS Construction, Program Data, Ground Rules and Assumptions, System Complexity, Interior, Avionics, Timephasing, Output. These modules can be accessed by selecting *CAICET* from the main menu. This results in a pull down menu appearing from which the individual modules can be accessed. Chart 1 portrays this and provides the structure for this document. Note: The modules must be run sequentially to ensure that CAICET has all of the needed inputs.

**CAICET**

- **WBS Construction**
- **Program Data**
- **Ground Rule & Assumptions**
- **System Complexity**
- **Interior**
- **Avionics**
- **Timephasing**
- **Output**

Figure 1. CAICET Modules

**WBS Construction**

The work breakdown structure (WBS) is the organizational chart of the product being estimated. The WBS is commonly referred to as a product-oriented family tree composed of hardware, software, services, training, support equipment, and management. The WBS should completely define the project being estimated and relate the elements of work to be accomplished to each other and to the end product (16:3). The purpose of the WBS is to breakdown the total system into manageable pieces or elements which graphically portray the way this work is to be accomplished. These elements are organized into a hierarchy of levels starting with level one and branching down as the item being estimated is segmented into smaller and smaller components. Level one is the overall system being estimated. Level two elements are major components of the system, such as Air Vehicle. Level three elements are subordinate to level two items. Based on the authors' experience, level four elements provide sufficient detail for this type of acquisition program. Thus, level four elements are the lowest elements in the CAICET Model.

Procedures

Selection of the *WBS Construction* from *CAICET* on the main menu will provide the analyst with the choice of using a default or existing WBS. Selection of *Use Default WBS*

provides the user with the SAM.DEF file. This file cannot be manipulated, therefore the user is prompted to save the file under a new file name with a WBS extension (ie TEST.WBS). Previously created files can be retrieved by selecting *Use Existing WBS* and then opening the file. The next step is to complete the Program Data section.

**Program Data**

Program Data includes Weapon System, Contractor, Estimate Date, Program Element (PE), Budget Program Activity Code (BPAC), Report Control Symbol, and Preparer. This information is used to complete sections of the AF Form 1537. A definition of each of these items is provided below:

- Weapon System: As the name states, it is the item or system being estimated. The CAICET Model contains a list of 18 types of aircraft which may be estimated.
- Contractor: The prime contractor contractually obligated to deliver the system.
- Estimate Date: As of date to appear on estimate.
- Program Element: The 11 Major programs are subdivided into program elements. The program element is the basic building block of the future years defense program (FYDP). It is defined as "an integrated combination of men, equipment, and facilities which together constitute an identifiable military capability or support activity." It identifies the mission to be undertaken and the organizational entities to perform the mission. Elements may consist of forces, manpower, materials, services, and/or associated costs as applicable. (17:1341).
- BPAC: Is a six digit alphanumeric code established for classification below the appropriation level to identify major budget programs. It is found in procurement and

Research, Development, Test, and Evaluation (RDT&E) fund cites only (17:652).

- Report Control Symbol: Is an internal number created for tracking and cataloging your estimates.

## Procedures

*Program Data* is selected from *CAICET* on the main menu. Upon selection of this module a dialog box appears on the screen prompting the user for the following items: Weapon System, Contractor, Estimate Date, PE, BPAC, Report Control Symbol, and Prepared by. The **Tab** key is used to move the cursor between input items. Once all blocks are completed select *OK*.

**Ground Rules & Assumptions**

Ground Rules & Assumptions (GR&A) are existing conditions and suppositions that provide the basis upon which an estimate is conducted (14: A-6,38). GR&A include the schedule (beginning and end dates) for all estimating tasks, the base year of the estimate, the cost units (dollars in thousands or millions), the appropriation (3010, 3600, etc), and the ability to either view or change the default inflation rates.

Procedures

The Ground Rules & Assumptions dialog box is accessed by selecting *Ground Rules & Assumptions* from the *CAICET* main menu. The following inputs are required:

*Estimate Base Year*
*Estimate Start Year*
*Estimate Start Month*
*Estimate End Year*
*Estimate Start Month*
*Inflation Rates*
*Appropriation*
*Cost Unit*

Once all choices have been made for this dialog box, the analyst is prompted to enter quantities for each fiscal year. Again the user can use the **Tab** key to move from field to field. All fields on this screen must be completed for CAICET to estimate correctly!

**System Complexity**

There are several WBS elements that are estimated through the use of cost factors. Regression analysis was used to determine the association between these cost factors and system complexity (reference Appendix A). System complexity refers to the relative difficulty involved with modifying a commercially available aircraft with various items. Complexity factors were based on Security System, Airstairs, Baggage Loader, Interior, and Communications. These items were chosen based on interviews with acquisition specialists (7) and an historical review of analogous programs. The system complexity module is used to retrieve the data needed to estimate the WBS elements that use cost factors as its estimating methodology. These cost elements are ECO, SE/PM, ST&E, Training, Data, and PSE. This module triggers the model to estimate the cost of the items selected, with the exception of interior which is estimated in the *Interior* module.

Procedures

The Systems Complexity dialog box is accessed by selecting *System Complexity* from the *CAICET* menu. The fields for Security, Airstairs, Baggage Loader, Interior, and Communications are selected based upon the complexity of the system being estimated. The choice of "Requires Customization" for Security, Airstairs, and Baggage Loader

is not active at this time; this selection was incorporated for future growth. Although not included in the System Complexity factor, the number of Auxiliary Power Units is input in this dialog box.

### Interior

The Interior module affords the user two methods for estimating the cost of an executive interior. The Cost Estimating Relationship (CER) method was derived through regression analysis, using cost as the dependent variable and interior square footage as the independent variable (reference Appendix B). The Catalog Price Model allows the user to select various items for installation in the aircraft (see the figure below).

| INTERIOR MODULE<br>Select Interior Items | Non-Recurring<br>Cost (CY$) | Recurring<br>Cost/Aircraft (CY$) | QTY |
|---|---|---|---|
| Galley | 110,900 | 277,250 | 1 |
| Hide-a-bed | 1,109 | 16,635 | 1 |
| TV/VCR Cabinet | 5,545 | 38,815 | 1 |
| VCR | | 12,199 | 1 |
| TV | | 13,308 | 1 |
| Business Class Seats | | 7,763 | 1 |
| Triple Business Class Seats | | 16,635 | 1 |
| First Class Seats | | 11,000 | 1 |
| Sleeper Seats | | 12,000 | 1 |
| Worktable | 3,327 | 12,199 | 1 |
| Worktable Seats | | 16,635 | 1 |
| Lavatory | | 110,900 | 1 |

Figure 2. Catalog Price Module

#### Procedures

The WBS element of Interior is estimated by selecting *Interior* from the *CAICET* menu. The user must then choose either *Cost Estimating Relationship* or *Catalog Price Model*. If *Cost Estimating Relationship* is selected, no further action is required; the CAICET model will compute the cost

based on the interior square feet of the aircraft. If *Catalog Price Model* is selected the user is then prompted to enter quantities for various items in the shaded area of the spreadsheet (reference the last column in the above figure).

## Avionics

The Avionics module is similar in construction to the Catalog Price Model described above. This module allows the user to select various avionics equipment and among several different manufacturers. This module acts similar to a shopping list. Just run through the list and enter quantities for the items you want. See the figure below for the Avionics worksheet.

| AVIONICS MODULE<br>Select Avionics Hardware | MODEL/DESCRIPTION | COST/<br>UNIT (CY$) | QTY |
|---|---|---|---|
| **Collision Avoidance System** | | | |
| Ryan Intl Corp | TCAD ATS 700: Panel-mount passive traffic alert | 4,975 | |
| BF Goodrich Flt Sys | TCAS 791: TCAS-1 system | 60,000 | |
| Honeywell, Inc | TCZ 910: Includes R/T's and one directional antenna | 106,544 | |
| Bendix/King | CAS 81: TCAS-II system, dual directional antenna | 195,950 | |
| **Global Positioning System** | | | |
| Trimble | Flightmate: 3 channel/No TSO/No IFR/LCD display | 995 | |
| Northstar | PS 600: 6 channel/TSO/No IFR/LED display | 4,995 | |
| II Morrow | NWS 2001D: 8 channel/Pnd TSO/Pnd IFR/LED display | 7,495 | |
| **Flight Management System** | | | |
| II Morrow | 2001 GPS | 3,995 | |
| Internav | GC1200 | 19,000 | |
| Global Wulfsberg Sys | GNS 500A | 63,764 | |
| Honeywell, Inc | FMZ 800 | 106,075 | |
| Litton Aero Products | LTN 92 | 192,540 | |
| **VHF Navigation Receiver** | | | |
| Terra Corp | TN 200D: No TSO | 1,095 | |
| Becker Avionics, Inc | NR 3301: TSO C34c/C40a | 2,450 | |
| S-TEC Corp | VIR 351: TSO C36c/C40a | 4,403 | |
| **Transponder** | | | |
| Bendix/King | KT 76A: TSO C47c Class 1A | 1,420 | |
| Bendix/King | TRS 42: TSO C74c Class 1A | 12,460 | |
| Collins Avionics Gr | TDR 94D: TSO C112 Class 3 | 29,600 | |

Figure 3. Avionics Module

| | | | |
|---|---|---|---|
| **FF/TACS/TACAN** | | 25,000 | |
| **Microwave Landing System** | | | |
| Bendix/King | MLS 21 | 24,750 | |
| Honeywell, Inc | MLZ 850 | 28,134 | |
| Canadian Marconi Co | CMA 2000 "Microlander" | 28,800 | |
| **LORAN** | | | |
| II Morrow | Flybuddy 820: Single Receiver/No TSO/No IFR/LCD | 1,195 | |
| Bendix/King | KLN 88: One channel/C60b TSO/IFR/CRT display | 5,975 | |
| Arnav | Arnav 7000: Multi Receiver/TSO/IFR/LED display | 9,995 | |
| **Color Weather Radar** | | | |
| Narco Avionics, Inc | KWX 56: 2 units/18 lbs/3 colors | 12,756 | |
| Bendix/King | RDS 84VP: 2 units/37.27 lbs/4 colors | 43,305 | |
| Honeywell, Inc | Primus 700: 4 units/38 lbs/5 colors | 95,173 | |

Figure 3. Avionics Module Continued

## Procedures

The Avionics module is accessed in the same manner as the previously mentioned modules. Select *CAICET* from the main menu and then select *Avionics* from the pull down menu. This will result in an Alert message telling the user to enter quantities in the shaded area. The next screen to appear is the Avionics worksheet as shown in the figure above.

**Timephasing**

After the costs of an element have been estimated, the next step is to allocate the estimate to specific fiscal years. The process of allocation is referred to as timephasing the estimate. Consideration must be given to any factors which may impact this spreading process.

The appropriation from which the program will be funded is one of the most important considerations. The full funding concept requires that Aircraft Procurement Appropriation costs for a given end item buy be funded in the fiscal year of the contractual obligation of funds regardless of the fiscal year in which the costs are actually incurred. Certain non-recurring requirements of a system, such as non-recurring production costs, system test, and site activation, may be funded in fiscal years subsequent to the year in which the end item is funded. This type of timephased procurement is a management tool to schedule procurements without tying up resources for extended periods. The required Initial Operational Capability (IOC) date is another factor to consider. The IOC date is one of the primary factors in determining the schedules which form one of the underlying assumptions of the cost estimate. Other considerations include: availability of funds, production rates, and buy quantities (14:12-3).

As the production appropriation is funded under the full funding concept, generally all that is required to timephase a production estimate is the period in which the quantities will be procured. However, some adjustments are necessary for the non-recurring requirements of the system. These costs may be spread based on historical cost data, program milestones, analogies, or contractor proposals. Methods for timephasing costs include the S-Curve and By Quantity.

Procedures

To timephase the estimate the analyst selects *Timephasing* from the *CAICET* pull-down menu. This takes the user to the Timephasing Module. The first step is for the analyst to put the cursor on the row of the WBS element to be time-phased. The next step is then to choose either *S-Curve* or *By Quantity*. A brief discussion of each of the S-Curve and By Quantity methods follows, with associated procedures.

**S-Curve**

The S-Curve is a percentage time to percentage cost allocation technique used to spread funding requirements once they have been determined. This forecasting tool is based on statistical distribution curves incorporated from the ASC Cost Workstation. The percentage of dollars is forecasted as a function of the percentage of time using normal or skewed distribution curves. An S-Curve of X/Y means that X percent of the resources are expended in Y percent of the time (13:4-83). The primary advantage of this method is that only the beginning and end dates of the work effort, not detailed schedule information, are required. The disadvantage of this technique is that the exact shape of the curve can only be determined from other sources, such as historical cost data on other programs. The S-Curve method of timephasing is used by the selection of an appropriate S-Curve that best represents the analyst's concept of how the cost for the particular WBS element should be phased. For example, an S-Curve of 15/85 means that 15 percent of the resources will be expended in 85 percent of the time.

For those cost elements which rely on the S-Curve spreading technique, the authors have provided the user with insight as to which distribution to use. The authors feel that this is a good area for sensitivity analysis. For example, change the 15/85 S-Curve to a 30/70 curve. If the

is little appreciable change in cost, then the cost for this element is not cost sensitive to the chosen S-Curve.

### Procedures

After the analyst has chosen to use the S-Curve for the particular WBS element, he then moves the pointer to the *S-Curve* button. A pull-down menu is then displayed on the screen offering several S-Curve ratios. The analyst chooses the appropriate selection.

**By Quantity**

"By Quantity" is a timephasing technique in which the analyst allocates the estimated costs associated with each aircraft according to the buy schedule.

Procedures

If By Quantity is desired as the timephasing method, the *By Quantity* button should be selected. The model will then perform the necessary calculations.

**Output**

This selection of *Output* from the *CAICET* pull-down menu provides the analyst with the capability of printing AF Forms 1537 in both Base Year and Then Year, along with the Catalog Price Model, Avionics Module, and Timephasing Module spreadsheets.

Procedures

Select Output from the main menu. The model will automatically print out the aforementioned pages.

**Updating the Database**

The database will require periodical updating. The following is a list of procedures for performing this function:

1. Open File Manager
2. Select CAICET
3. Select MRMCV.XLS file
4. Select F5 key
5. Select desired module from menu
6. Make changes to spreadsheet
7. Save the spreadsheet
8. Exit Excel
9. Exit File Manager

Each section of the spreadsheet which requires updating references source material.

## Estimating Guide for SAM fleet Aircraft

### SAM Fleet WBS

As stated in the previous section, the SAM.DEF file contains an existing WBS specifically designed for the estimation of commercial aircraft for introduction into the Special Air Missions Fleet. The following diagram portrays this WBS.

| Level | Element |
|---|---|
| 1 | Aircraft System |
| 2 | Air Vehicle |
| 3 | Basic Aircraft |
| 3 | Interior |
| 3 | Avionics |
| 3 | Communications |
| 3 | Self-Sufficiency |
| 3 | Self Defense System |
| 3 | Auxiliary Power Unit |
| 2 | Engineering Change Orders |
| 2 | System Engineering/Program Management |
| 2 | System Test & Evaluation |
| 2 | Training |
| 2 | Data |
| 2 | Peculiar Support Equipment |
| 2 | Site Activation |
| 2 | Initial Spares |

Figure 4. Work Breakdown Structure

For each WBS element to be estimated a detailed description of the element, methods to be employed in estimating its costs, and relevant cost data are provided.

**Aircraft System**

The Aircraft System is the total product to be estimated. This includes all acquisition costs associated with the cost of procuring and modifying commercial aircraft for the Special Air Mission fleet. The Aircraft System is estimated by aggregating the costs of all Level 2 cost elements (reference Figure 4).

### Air Vehicle

The Level 2 element Air Vehicle is divided into the Level 3 elements of Basic Aircraft, Interior, Avionics, Communications, Self-Sufficiency, Self Defense System, and Auxiliary Power Unit. Air Vehicle is estimated by aggregating the costs of these cost elements.

**Basic Aircraft**

The Basic Aircraft is further subdivided into Airframe and Paint. The Airframe may be estimated by using market prices as listed in the Avmark Newsletter (18). Avmark, Inc., a worldwide aviation marketing and management service, publishes the market prices of commercial aircraft in January and July issues of its monthly newsletter. Prices are in current dollars and are list or approximate manufacturer list prices for single or other small orders (reference Figure 5).

| Airframe Manufacturer | Type | Market Price Jan-93 |
|---|---|---|
| Airbus | A300-600R | 70,500,000 |
| | A310-300 | 66,500,000 |
| Boeing | B737-300 | 27,500,000 |
| | B737-400 | 31,000,000 |
| | B737-500 | 26,500,000 |
| | B747-400 | 132,000,000 |
| | B757-200 | 42,000,000 |
| | B757-200PF | 49,000,000 |
| | B767-200 | 52,000,000 |
| | B767-200ER | 62,000,000 |
| | B767-300 | 66,000,000 |
| | B767-300ER | 72,000,000 |
| Gulfstream | G-IV | 21,077,901 |
| MD | MD-11 | 95,000,000 |
| | MD-81 | 22,000,000 |
| | MD-82 | 27,000,000 |
| | MD-83 | 28,000,000 |
| | MD-87 | 24,500,000 |

Figure 5. New Commercial Aircraft Market Prices

The CAICET Model computes the cost of the airframe based upon the selection of Weapon System in the Program Data dialog box.

The cost of painting the exterior of a VIP aircraft is estimated using a CER based upon historical cost data. A factor has been computed using the OC-ALC VC-137 contract (number F34501-88C-2500); the contract price for this painting effort was $394,000 and the aircraft had a wingspan of 142'5". The variable for the equation is the wingspan of the aircraft, which is listed in the MRMCV.XLS file under the "library" title of PAINT. The CER equation is as follows:

$$\boxed{Cost = \$2,776 * (Wingspan\ )}$$

Again, the CAICET Model computes the cost of the paint based upon the selection of Weapon System in the Program Data dialog box. By making that selection, CAICET retrieves the wingspan for the aircraft and computes the paint cost.

**Interior**

Costs associated with an executive interior may be estimated using a CER or catalog prices. The CER approach was created to provide the analyst the means to estimate an interior which **requires** customization. An example of this type of customization is moving hardpoints, installing non-standard items that are not commercially available, and cutting holes in the airframe. These types of modifications are analogous to those made on AF-1. The regression equation for this CER is:

$$InteriorCosts = -2990570.0 + 390342.5 * \sqrt{SQFT}$$

Documentation for this CER is contained in Appendix B.

Interior costs of aircraft which do not require customization can be estimated using catalog prices (19,20). The non-recurring and recurring costs for various items (reference Figure 2) are provided in the Interior module in order to estimate using the grassroots approach. Non-recurring costs are associated with the first unit costs. These costs include such items as design, engineering drawings, and certification. Recurring costs refer to the recurring installation costs associated with the product. Some estimators would classify these costs under Group A Install and Checkout. Quantities are entered in the shaded areas.

**Avionics**

This element includes avionics which are not typically furnished on commercially available aircraft. In other words, a military specific avionics cluster of items which are not furnished as standard equipment but are commercially available. As such, these items should be estimated via catalog prices. The non-recurring and recurring costs for various items, including different qualities and options within each item, are provided in the Avionics module (reference Figure 3). The source of this cost data is a contractor ROM (19) for non-recurring and recurring installation costs and the Business & Commercial Aviation 1993 Planning & Purchasing Handbook (21) for individual avionic components. This handbook provides the market prices for various avionics items. It is important that this portion of the database is updated on a routine basis.

**Communications**

There are various grades of Mission Communication System (MCS) options contained within the CAICET Model. The SOUTHCOM type communication system provides a secure SATCOM and a passenger information system. It is considered by the Aircraft System SPO personnel (7) that this would not be sufficient for a SAM configured aircraft. This option was included in the database to show the impact of MCS on the overall cost of these aircraft. The C-20H type MCS configuration is probably the minimum acceptable by the user. This system includes: UHF/VHF FM, SATCOM, STU III, INMARSAT and limited switching capability. The BUS architecture has been established as the baseline communication system by the White House Communications Agency (8). The BUS configuration includes all of the items in the C-20H system plus DAMA, Frequency Management, SELSCAN, JAM, and expanded switching capability. CAICET estimates the mission communication system based on the selection in the communications block of the System Complexity dialog box. The C-20H type MCS cost was estimated using actual costs for the C-20H MCS. The BUS configuration MCS was estimated using a contractor ROM (19).

**Self-Sufficiency**

The user requires that aircraft configured for introduction into the SAM fleet maintain a certain degree of self sufficiency. This includes airstairs, perimeter security system and baggage loader. The cost for Self-Sufficiency is estimated as the aggregate of these level four elements. Airstairs provide the ability for the passengers to disembark the aircraft without the use of ground support equipment. This element is estimated using a contractor ROM (19). The perimeter security system is an intrusion detection system for the aircraft while on the ground. The cost for this element is estimated with a contractor ROM cited by the VC-X Requirements Trade-Off Study (11). The baggage loader provides the ability for passenger baggage to be onloaded and offloaded without ground support equipment. This element is estimated by the use of market prices provided in the Business & Commercial Aviation 1993 Planning & Purchasing Handbook. CAICET estimates the self-sufficiency items using the selections in the appropriate blocks of the System Complexity dialog box.

**Self Defense System**

This cost element encompasses the aircraft's ability to defend itself against ground launched missiles. The Self Defense System (SDS), is acquired off-the-shelf from the commercial sector and is comparable to that of the AF-1. An SDS unit is required for each engine and the Auxiliary Power Unit of the aircraft. The cost of one unit is estimated to be $250,000 (BY91$). This estimate was provided by VC-X Program Office personnel (ASC/SDC) and is documented in the VC-X Requirements Trade-Off Study. This is a firm requirement, therefore, CAICET includes the cost for an SDS in each estimate.

If the user requires a system more sophisticated than the SDS on AF-1, the analyst is advised to contact ASC/RW. This program office is currently in the process of developing a next-generation all-aspects SDS.

**Auxiliary Power Unit**

The user's power requirements are such that an APU will probably be required. Components which drive the power requirements include: additional avionics, MCS, SDS, security system, entertainment system, baggage loader, airstairs, and galley. The using command has mandated that only commercially available APUs will be acquired (7). This decision was made to lower costs and eliminate development items. The CAICET Model computes the cost for APUs, derived from AF-1 history, based upon the quantity entered in the "Number of APUs" block of the System Complexity dialog box.

## Engineering Change Orders

This element is included as a reserve in the estimate for known unknowns which are over and above allowances for risk. Typically when estimating these types of aircraft a factor of four percent is applied to the sum of Air Vehicle and SE/PM costs (11). CAICET allows the analyst to spread these costs according to an S-Curve distribution. The user provides this information in the Timephasing module. Based on past experience, the authors suggest front-loading this element. An example of this type of spread is a 60/40 S-Curve.

## Systems Engineering and Program Management

This cost element refers to systems engineering and technical control as well as the business management of the system. System engineering encompasses design reviews, monitoring, and control of subcontractors, data items, reliability, maintainability, availability, and system safety programs. Program management refers to planning, directing, and controlling the definition, development, and production of the systems. SE/PM costs are estimated as a percentage of the Air Vehicle cost. Cost data from several past military purchases of commercial aircraft was analyzed. The ratio of SE/PM costs to Air Vehicle costs was compared to the modification efforts required in each program. Complexity factors (reference Appendix A) were used to quantify these modifications. Regression analysis was then used to derive an equation for predicting the SE/PM cost factor. Data on the C-20 and C-20H were not included in the data set used to run this analysis. This was due to the methods in which the prime contractor accounted for these costs. The C-20 contractor included some SE/PM costs in the interior cost element; and, the C-20H contractor included a portion of MCS integration in the SE/PM cost element.

The CAICET Model provides the analyst the ability to spread these costs according to an S-Curve distribution. This element is spread based on the input provided by the user in the Timephasing module. Based on past experience,

the authors suggest front-loading this element. The reason for this is that although program management is fairly constant throughout the effort the systems engineering portion is weighted toward the beginning. An example of this type of spread is a 55/45 S-Curve.

## System Test & Evaluation

This element encompasses the designing, planning, conducting, evaluating, and reporting of the testing necessary to verify crew station and passenger accommodation modification. The objective of the testing is to qualify the aircraft for FAA certification and to ensure that the system specifications are met. System Test & Evaluation (ST&E) costs are estimated as a percentage of the Air Vehicle cost. Cost data from several past military purchases of commercial aircraft were analyzed. The ratio of ST&E costs to Air Vehicle costs was compared to the modification efforts required in each program. Complexity factors (reference Appendix A) were used to quantify these modifications. Regression analysis was then used to derive an equation for predicting the ST&E cost factor.

In the Timephasing module, the user has the ability to spread these costs according to an S-Curve distribution. Again, based on past experience, the authors suggest front-loading this element. The reason for this is that most of the testing is done before IOC. A 65/35 S-Curve is representative of this profile.

## Training

This element includes all effort, hardware, and materials associated with the development and fabrication of all items for training equipment, facilities, and services for aircrew and maintenance/operator training. Training costs are estimated as a percentage of the Air Vehicle cost. Cost data from several past military purchases of commercial aircraft were analyzed. The C-27 was eliminated from the data set because it was produced by an Italian manufacturer and training material had to be translated. This resulted an above average cost for training. The C-20 was not included because training costs were not available. A composite factor was then derived by aggregating the Training costs and dividing by the aggregate of the Air Vehicle costs. This method was chosen because the cost factors were fairly constant for all aircraft (reference Appendix A).

The CAICET Model provides the user with the ability to spread these costs according to an S-Curve distribution. The costs of this element are usually spread such that the greatest percentage is allocated near IOC for training of an initial cadre. Thus, the authors suggest front-loading this element. A 70/30 S-Curve is representative of this profile.

## Data

This element contains all data deliverable under the Contract Data Requirements List (CDRL). It includes the acquisition, writing, assemblage, reproduction, packaging, and shipping of data. Data costs are estimated as a percentage of the Air Vehicle cost. Cost data from several past military purchases of commercial aircraft were analyzed. The ratio of Data costs to Air Vehicle costs was compared to the modification efforts required in each program. Complexity factors (reference Appendix A) were used to quantify these modifications. Regression analysis was then used to derive an equation for predicting the Data cost factor.

Note that the factor for data is higher than you would see used in estimating other military aircraft procurements. This is due to the fact that the Air Force requires that the commercially available flight manuals and technical manuals be rewritten to military specifications (7).

The user may spread these costs using the Timephasing module of the CAICET Model. This element is commonly front end loaded. We suggest a 55/45 S-Curve be used when spreading the costs of this element.

## Peculiar Support Equipment (PSE)

This element contains the costs for all operational level tools and equipment required in the servicing and daily maintenance of the system being procured. This includes unique aerospace ground equipment required to support and maintain special equipment and hardware (14: A-54). The PSE cost element is estimated based on data from the VC-X Requirements Trade-Off Study (11). This data was used to compute a PSE cost factor (as a percent of Air Vehicle). The PSE cost factor is adjusted using a complexity factor (reference Appendix A) derived by acquisition specialists based on the modification efforts required in each program. PSE is usually purchased up front to make facilities ready for IOC. The authors suggest a 85/15 S-Curve.

## Site Activation

This element includes all costs associated with bringing a site to a state of operational readiness. This includes facility construction, installation and checkout of all system and supporting equipment, travel costs, site survey, and training costs associated with the facilities.

There is no hard and fast estimating technique that we can offer for this cost element. We will provide you with a series of question to ask yourself and others to get you pointed in the right direction.

1. Are facilities required?
2. Is the facility adequate with the addition of your procurement?
3. Is there adequate hanger space?
4. Does the user want the aircraft to be able to be totally enclosed in the hanger?
5. Is the current support equipment sufficient?
6. Are temporary facilities needed phase-in?

This element is usually spread toward initial operational capability (IOC). The site has to be operational by the delivery of the first aircraft. For further information on this cost element reference The AFSC Cost Estimating Handbook starting on page 11-16.

**Initial Spares**

This cost element includes all costs associated with the stocking of a spares pipeline. A factor of 10% of recurring costs is used to estimate this element. This estimating method was used in both the C-20H estimate and the VC-X Requirements Trade-Off Study. These items are spread using the *By Quantity* option in the Timephasing module.

## V. Conclusion

The purpose of this research was to develop a cost estimating model which would allow cost estimators the ability to quickly and accurately estimate the acquisition of Air Force Special Air Mission fleet aircraft. The CAICET Model provides the analyst with the ability to estimate an acquisition program based on a few specific parameters concerning the missionization of the aircraft. These parameters include interior configuration, avionics, mission communications, and self-sufficiency items.

From the CAICET pull-down menu the analyst can quickly and methodically process through the required modules. Each of these modules will offer several alternatives and prompts the user for the required response. For example, the interior module allows the user to either estimate this cost element using a CER or by providing the user a quasi-shopping list of 12 items. The avionics module offers the user nine types of avionics hardware with a total of 28 options. Once this information is input, the CAICET Model provides the analyst with a real-time estimate in standard AF Form 1537 format.

The CAICET Model was field tested in a series of "What-If" exercises generated by SAF/XOFM in July 1993. The results were favorably received and forwarded to CSAF.

## Appendix A: Documentation of System Complexity Matrix

Appendix A serves as documentation for the system complexity matrix. There were three steps taken in the development of this matrix. The first step was to develop complexity factors to serve as the independent variable. The following matrix was used to relate the complexity of modifications to cost factors for the following cost elements: System Engineering/Program Management, System Test & Evaluation, Training, Data, and PSE. Inputs from ASC/SDC (7) and industry (19) were used to quantify these complexity factors.

**Calculation matrix for Complexity Factor**

| Cost Driver | Option | Complexity Scale | AF-1 | C-26 | C-27 | C-23 | C-29 | C-20H | C-20 |
|---|---|---|---|---|---|---|---|---|---|
| Interior | First Class SeatsOnly | 1 | | 1 | 0 | 1 | | | |
| | Commercial Executive | 3 | | | | | 3 | 3 | 2 |
| | Customized Executive | 5 | 5 | | | | | | |
| MCS | SOUTHCOM Type | 1 | | 1 | 1 | 1 | 1 | | |
| | C-20H Type | 3 | | | | | | 3 | 3 |
| | BUS Architecture | 7 | 7 | | | | | | |
| Self Sufficiency | Baggage Loader | | | | | | | | |
| | Not Required | 0 | | 0 | 0 | | 0 | | |
| | Commercially Available | 1 | | | | | | | |
| | Requires Customization | 2 | 2 | | | 2 | | | |
| | Security System | | | | | | | | |
| | Not Required | 0 | | 0 | 0 | 0 | | | |
| | Commercially Available | 1 | | | | | 1 | 1 | 1 |
| | Requires Customization | 2 | 2 | | | | | | |
| | Airstairs | | | | | | | | |
| | Not Required | 0 | | 0 | 0 | 0 | 0 | | |
| | Commercially Available | 1 | | | | | | | |
| | Requires Customization | 2 | 2 | | | | | 0 | |
| | Complexity Total | | 18 | 2 | 1 | 4 | 5 | 7 | 6 |

Calculation Matrix for Complexity Factor

A description of these options is as follows:

**First Class Interior** Commercially available galleys, seats, and lavatories which require no modification

**Commercial Executive Interior** Commercially available executive galleys, hide-a-beds, entertainment systems, seats, worktables, and lavatories which require no modification, but do include some design effort

**Customized Executive Interior** Custom executive galleys, hide-a-beds, entertainment systems, seats, worktables, and lavatories which require significant design and modification (including moving hardpoints, cutting holes, re-plumbing)

**SOUTHCOM Type MCS** No switching system, secure SATCOM UHF/HF

**C-20H Type MCS** Minimal switching

**BUS Architecture MCS** State-of-the-art switching system, fiber-optic backbone with coaxial cables

**Self-Sufficiency Items which are Commercially Available** An item which has previously been designed and FAA certified for the aircraft under consideration

**Self-Sufficiency Items which Require Customization** Such an item which has not been previously designed or FAA certified and the aircraft under consideration would have to be modified for adaptation.

The second step was to use regression analysis to determine a relationship between the independent variable (complexity factor) and the dependent variable (cost factor). The relationships for Training and PSE were not

statistically significant; therefore, alternative techniques were used to estimate these WBS elements. The following pages serve as documentation for this process.

The analysis of variance (ANOVA) approach (15:92-104) to regression analysis is used to determine the variability of the data. This approach is based on the partitioning of sums of squares and degrees of freedom associated with the dependent variable. The variation of the data around the regression line is referred to as unexplained error or uncertainty and is the variation not accounted for. The variation of the fitted regression line around the mean is referred to as explained error and is the variation that is attributed to the equation.

An ANOVA table breaks down the total sum of squares for the dependent variable into the portion that is referred to as explained error and unexplained error. From the ANOVA table, several miscellaneous statistics can be calculated and evaluated. These include: F-Statistic, T-Statistic, P-value, R-Square, and Adjusted R-Square.

**F-Statistic** This value is the ratio produced by dividing Mean Square Regression by Mean Square Residual tests how well the model accounts for the dependent variable's behavior.

**T-Statistic** This test checks the significance of the intercept and coefficients. This value is the ratio produced by dividing the coefficient by the standard error.

A large value for the T-Statistic indicates that the value of the parameter is not likely to equal zero, and therefore the independent variable contributes significantly to the model.

**P-value** This value for a sample outcome is the smallest alpha for which we can reject the null hypothesis. A very small p-value indicates significance. This definition holds for the Significance F value.

**R-Square** This value is referred to as the coefficient of determination and is a measure of the explained error. If all observations fall on the fitted regression line this value would equal 1. This is an example where the independent variable X accounted for all the variation in the observations Y. It is unlikely that $R^2$ will equal 1 in reality, therefore, the closer to one the greater the linear association between the X and Y variable. Therefore, in general, the closer the $R^2$ value is to one, the better the fit.

**Adjusted R-Square** Adjusts the $R^2$ by dividing each sum of squares by its associated degrees of freedom. Therefore, the adjusted $R^2$ may actually become smaller as you introduce another independent variable into the model.

**Residuals** The residuals are defined as the difference between the actuals and the values predicted by the model. The sum of the residuals for the model equals zero.

Each fitted regression line is analyzed using the statistics above. A table is provided which lists expectations and results for each statistic. This is followed by the Regression Analysis output of Excel and a short discussion of the results.

**Documentation for the Sys Eng / Prog Mngt Factor**

The factor to predict the cost of SE/PM was based on data of historical military acquisitions of commercial aircraft. We estimated that the SE/PM cost factor is a function of the modifications to the aircraft. Complexity factors for these modifications were provided by acquisition specialists. We used regression analysis to verify this relationship. The results of the regression run are provided below.

| Statistic | Model |
|---|---|
| F Statistic | 278.16 |
| Significance F | 0.0005 |
| T-Statistic $b0$ | 12.59 |
| P-value | 0.0002 |
| T-Statistic $b1$ | 16.68 |
| P-value | 0.0001 |
| R-Square | 0.9893 |
| Adjusted R-Square | 0.9858 |

The R-Square value of 98.93% shows a significant "goodness of fit" for the regression equation. The Significance F of 0.0005 provides significant evidence that there is a linear relationship between the independent and dependent variables. The Regression Analysis output of

Excel is provided below. The residual matrix shows that the maximum deviation within the database was 8.92%.

**Regression for SE/PM Matrix**

| | Complexity | Factor |
|---|---|---|
| AF-1 | 18 | 9.77 |
| C-26 | 2 | 3.58 |
| C-27 | 1 | 3.22 |
| C-23 | 4 | 3.80 |
| C-29 | 5 | 4.27 |

*Regression Statistics*

| | |
|---|---|
| Multiple R | 99.47% |
| R Square | 98.93% |
| Adjusted R Square | 98.58% |
| Standard Error | 0.33 |
| Observations | 5 |

*Analysis of Variance*

| | *df* | *Sum of Squares* | *Mean Square* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 29.57 | 29.57 | 278.16 | 0.0005 |
| Residual | 3 | 0.32 | 0.11 | | |
| Total | 4 | 29.88 | | | |

| | *Coefficients* | *Standard Error* | *t Statistic* | *P-value* |
|---|---|---|---|---|
| Intercept | 2.56 | 0.20 | 12.59 | 0.0002 |
| x1 | 0.39 | 0.02 | 16.68 | 0.0001 |

| *Observation* | *Predicted Y* | *Residuals* | *% Delta* |
|---|---|---|---|
| 1 | 9.66 | 0.11 | 1.11% |
| 2 | 3.35 | 0.23 | 6.42% |
| 3 | 2.96 | 0.26 | 8.21% |
| 4 | 4.14 | -0.34 | -8.92% |
| 5 | 4.53 | -0.26 | -6.17% |

**Documentation for the Test & Evaluation Factor**

The factor to predict the cost of Test & Evaluation (T&E) was based on data of historical military acquisitions of commercial aircraft. We estimated that the T&E cost factor is a function of the modifications to the aircraft. It stands to reason that the more an aircraft is modified, the more test and evaluation would be needed for certification. Complexity factors of these modifications were provided by acquisition specialists. We used regression analysis to verify this relationship. The results of the regression run are provided below.

| **Statistic** | **Model** |
|---|---|
| F Statistic | 10.41 |
| Significance F | 0.0321 |
| T-Statistic $b0$ | 2.48 |
| P-value | 0.0560 |
| T-Statistic $b1$ | 3.23 |
| P-value | 0.0233 |
| R-Square | 0.7223 |
| Adjusted R-Square | 0.6529 |

The R-Square value of 72.23% shows a somewhat less significant "goodness of fit" for the regression equation, compared to those previously documented. The Significance F of 0.0321 provides significant evidence that there is a

linear relationship between the independent and dependent variables. The Regression Analysis output of Excel is provided below. The residual matrix shows that the maximum deviation within the database was 81.78%. However, the range for the cost factor for this element is from a low of 0.44% to a high of 2.00%. Thus, the estimated total costs for this element could only deviate by a maximum of 1.56%.

**Regression Equation for Test & Eval**

| | Complexity | Factor |
|---|---|---|
| AF-1 | 18 | 2 |
| C-26 | 2 | 0.44 |
| C-27 | 1 | 0.68 |
| C-23 | 4 | 0.49 |
| C-29 | 5 | 1.46 |
| C-20 | 6 | 1.31 |

*Regression Statistics*

| | |
|---|---|
| Multiple R | 84.99% |
| R Square | 72.23% |
| Adjusted R Square | 65.29% |
| Standard Error | 0.3688 |
| Observations | 6 |

*Analysis of Variance*

| | *df* | *Sum of Squares* | *Mean Square* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 1.4156 | 1.4156 | 10.4057 | 0.0321 |
| Residual | 4 | 0.5442 | 0.1360 | | |
| Total | 5 | 1.9597 | | | |

| | *Coefficients* | *Standard Error* | *t Statistic* | *P-value* |
|---|---|---|---|---|
| Intercept | 0.5454 | 0.2201 | 2.4780 | 0.0560 |
| x1 | 0.0863 | 0.0268 | 3.2258 | 0.0233 |

| Observation | Predicted Y | Residuals | % Delta |
|---|---|---|---|
| 1 | 2.10 | -0.10 | -4.96% |
| 2 | 0.72 | -0.28 | -63.20% |
| 3 | 0.63 | 0.05 | 7.09% |
| 4 | 0.89 | -0.40 | -81.78% |
| 5 | 0.98 | 0.48 | 33.08% |
| 6 | 1.06 | 0.25 | 18.83% |

**Documentation for the Data Factor**

The factor to predict the cost of Data was based on data from Air Force history of commercial derivative aircraft programs. We estimated that the Data cost factor is a function of the modifications to the aircraft. When you buy a commercial aircraft, the data required for operation of the aircraft is included in the price of the aircraft. However, modifications to the aircraft necessitate purchasing additional data, therefore increasing the cost of data. Again, complexity factors for these modifications were provided by acquisition specialists (7). Regression analysis was used to verify the relationship between the cost and complexity factors. The results of the regression run are provided below.

| **Statistic** | **Model** |
|---|---|
| F Statistic | 3.18 |
| Significance F | 0.1725 |
| T-Statistic $b0$ | 9.57 |
| P-value | 0.0007 |
| T-Statistic $b1$ | 1.78 |
| P-value | 0.1491 |
| R-Square | 0.5146 |
| Adjusted R-Square | 0.3528 |

Although the R-Square value of 51.46% is somewhat low,

this regression equation was incorporated into the model based on its F Satistic and associated Significance F. The Significance F of 0.1725 provides evidence that there is a linear relationship between the independent and dependent variables. The Regression Analysis output of Excel is provided below. The residual matrix shows that the maximum deviation within the database was 15.96%. The range for the cost factor for this element is from a low of 2.33% to a high of 3.47%. Thus, the estimated total costs for this element may deviate by a maximum of 1.14%.

**Regression Equation for Data**

| | Complexity | Factor |
|---|---|---|
| AF-1 | 18 | 3.30 |
| C-27 | 1 | 2.33 |
| C-23 | 4 | 2.66 |
| C-20H | 7 | 3.46 |
| C-20 | 6 | 2.84 |

*Regression Statistics*

| | |
|---|---|
| Multiple R | 71.73% |
| R Square | 51.46% |
| Adjusted R Square | 35.28% |
| Standard Error | 0.37 |
| Observations | 5 |

*Analysis of Variance*

| | df | Sum of Squares | Mean Square | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 0.44 | 0.44 | 3.18 | 0.1725 |
| Residual | 3 | 0.42 | 0.14 | | |
| Total | 4 | 0.86 | | | |

| | Coefficients | Standard Error | t Statistic | P-value |
|---|---|---|---|---|
| Intercept | 2.5476 | 0.27 | 9.57 | 0.0007 |
| x1 | 0.0515 | 0.03 | 1.78 | 0.1491 |

| Observation | Predicted Y | Residuals | % Delta |
|---|---|---|---|
| 1 | 3.47 | -0.17 | -5.26% |
| 2 | 2.60 | -0.27 | -11.55% |
| 3 | 2.75 | -0.09 | -3.51% |
| 4 | 2.91 | 0.55 | 15.96% |
| 5 | 2.86 | -0.02 | -0.57% |

## Documentation for Training Factor

The training cost factor was derived using the following data:

**Computation of factor for Training Costs**

| Aircraft | Airframe | Avionics | Interior | Air Vehicle Subtotal | Training | Trng as %Air Vehicle |
|---|---|---|---|---|---|---|
| C-26 | 17,395,957 | 4,185,493 | NSP | 21,581,451 | 95,125 | 0.44% |
| C-23 | 42,461,356 | 15,362,663 | 2,865,636 | 60,689,655 | 439,952 | 0.72% |
| C-29 | 51,022,592 | 17,027,348 | 237,812 | 68,287,753 | 249,703 | 0.37% |
| AF-1 | 186,254,459 | 5,743,163 | 40,959,806 | 232,957,428 | 725,327 | 0.31% |
| C-20H | 20,973,483 | 14,548,110 | 3,666,551 | 39,188,143 | 368,483 | 0.94% |
| C-27 | 144,762,115 | 11,140,911 | 779,166 | 156,682,192 | 1,883,954 | 1.20% |
| Composite | 462,869,961 | 68,007,689 | 48,508,971 | 579,386,622 | 3,762,544 | 0.65% |
| Comp W/O C-27 | 318,107,846 | 56,866,778 | 47,729,805 | 422,704,429 | 1,878,590 | 0.44% |

**Documentation for Peculiar Support Equip Factor**

The cost for PSE was estimated with cost data from the VC-X Requirements Trade-Off Study. Costs were linearly distributed.

## System Complexity Matrix

The final step was to develop the System Complexity Matrix. The matrix synopsized the results of the regression equations for the applicable WBS elements. The matrix also provided a format for the model to relate a complexity factor to its corresponding cost factor.

**Matrix for chosing factors**

| Complexity | SE/PM | Test & Eval | Data | PSE |
|---|---|---|---|---|
| 1 | 2.96% | 0.63% | 2.60% | 1.30% |
| 2 | 3.35% | 0.72% | 2.65% | 1.39% |
| 3 | 3.74% | 0.80% | 2.70% | 1.48% |
| 4 | 4.14% | 0.89% | 2.75% | 1.57% |
| 5 | 4.53% | 0.98% | 2.80% | 1.66% |
| 6 | 4.93% | 1.06% | 2.86% | 1.75% |
| 7 | 5.32% | 1.15% | 2.91% | 1.84% |
| 8 | 5.72% | 1.24% | 2.96% | 1.93% |
| 9 | 6.11% | 1.32% | 3.01% | 2.02% |
| 10 | 6.51% | 1.41% | 3.06% | 2.11% |
| 11 | 6.90% | 1.49% | 3.11% | 2.20% |
| 12 | 7.29% | 1.58% | 3.16% | 2.29% |
| 13 | 7.69% | 1.67% | 3.22% | 2.38% |
| 14 | 8.08% | 1.75% | 3.27% | 2.47% |
| 15 | 8.48% | 1.84% | 3.32% | 2.56% |
| 16 | 8.87% | 1.93% | 3.37% | 2.65% |
| 17 | 9.27% | 2.01% | 3.42% | 2.74% |
| 18 | 9.66% | 2.10% | 3.47% | 2.83% |

## Appendix B: Documentation for Interior CER

Appendix B serves as the documentation for regression analysis used in deriving the Interior CER within the CAICET Model. The first step was to determine what was the logical independent variable. We hypothesized that interior square footage was the cost driver and hence a logical independent variable. The next step was to theorize as to the shape of this relationship. We believed that these costs would be increasing at a decreasing rate. Therefore, we decided to run the regression by taking the square root of the independent variable. The results of the regression run are provided below.

| Statistic | Model |
|---|---|
| F Statistic | 851.02 |
| Significance F | 0.0001 |
| T-Statistic $b0$ | -6.06 |
| P-value | 0.0037 |
| T-Statistic $b1$ | 29.17 |
| P-value | 0.0001 |
| R-Square | 0.9965 |
| Adjusted R-Square | 0.9953 |

The R-Square value of 99.65% shows a significant "goodness of fit" for the regression equation. The Significance F of 0.0037 indicates that the transformed equation provides a linear relationship between the independent and dependent variables. The Regression Analysis output is provided below. The residual matrix shows the maximum deviation within the database was 14%.

**Data for CER regression model for interior cost**

| Aircraft | Interior | SQ FT | SQRT(SQFT) |
|---|---|---|---|
| C-20G | 2,733,353 | 227 | 15.07 |
| AF-1 | 20,479,903 | 3,527 | 59.39 |
| C-20H | 3,666,551 | 247 | 15.72 |
| B757-200 | 9,939,479 | 1,200 | 34.64 |
| B767-200 | 12,561,112 | 1,600 | 40.00 |

*Regression Statistics*

| | |
|---|---|
| Multiple R | 99.82% |
| R Square | 99.65% |
| Adjusted R Square | 99.53% |
| Standard Error | 494971.52 |
| Observations | 5 |

*Analysis of Variance*

| | df | Sum of Squares | Mean Square | F | Significance F |
|---|---|---|---|---|---|
| Regression | 1 | 2.08E+14 | 2.08E+14 | 851.02 | 0.0001 |
| Residual | 3 | 7.35E+11 | 2.45E+11 | | |
| Total | 4 | 2.09E+14 | | | |

| | Coefficients | Standard Error | t Statistic | P-value |
|---|---|---|---|---|
| Intercept | -2990570.86 | 493489.89 | -6.06 | 0.0037 |
| x1 | 390342.50 | 13380.64 | 29.17 | 0.0000 |

| Observation | Predicted Y | Residuals | % Delta |
|---|---|---|---|
| 1 | 2,890,532 | -157,179 | -5.75% |
| 2 | 20,191,304 | 288,599 | 1.41% |
| 3 | 3,144,143 | 522,408 | 14.25% |
| 4 | 10,531,290 | -591,811 | -5.95% |
| 5 | 12,623,129 | -62,017 | -0.49% |

## Appendix C: Cost Estimate Example Using CAICET

It is 1645 hours and you've just received a "What-If" from SAF/AQ. They need a cost estimate by 1700 hours for this scenario: Six B767-200 modified with airstairs, security system, and baggage loader, and SDS. The aircraft will also require an avionics cluster and an executive interior to include 3 galleys, one Hide-A-Bed, a TV/VCR entertainment system, 60 business class seats, 18 sleeper seats, three worktables, and five lavatories. They also stated that the user requires an MCS of similar configuration to that found on the C-20H. They asked for the estimate in Base Year 1994 Dollars. The program is to start up in 1994, with two aircraft modified each year. What do you do?

First you turn to your friendly engineer and ask what avionics need to be included. He gives you a long list of items (note input for Avionics Module below). The next question concerns power for the self-sufficiency items. Is addition power required to run these systems? He says an APU is required. Armed with your answers, you turn to CAICET. Here are the steps you will follow in completing your estimate:

Select CAICET Icon

Select *WBS Construction*

Select *Use Default WBS*

Select SAM.DEF

Save the file as TEST1.WBS (your choice)

Select *CAICET / Program Data*

Complete the Program Data dialog box as follows:

Weapon System: B767-200

Contractor: TBD

Estimate Date: Today

Program Element: TBD

BPAC: TBD

Report Control Symbol: SAF/AQ 1

Prepared by: Yourself

Select *CAICET / Ground Rules & Assumptions*

Complete the Ground Rules & Assumptions dialog box as follows:

Estimate Base Year: 1994

Estimate Start Year: 1994

Estimate Start Month: Oct

Estimate End Year: 1997

Estimate End Month: Sep

Inflation Rates: Use Current Rates

Appropriation: 3010 Aircraft Procurement Other

Cost Unit: $K

Model Prompt to Enter Quantities: 2 each in 1995, 1996, 1997

Select *CAICET / System Complexity*

Security System: Commercially Available

Airstairs: Commercially Available

Baggage Loader: Commercially Available

Interior: Commercial Executive

Communications: C-20H Configuration

Number of APUs: 1

Select *CAICET / Interior / Catalog Price Model*

Model Prompt to Enter Quantities in Shaded Areas

Fill out this module as shown below:

| INTERIOR MODULE<br>Select Interior Items | Non-Recurring Cost | Recurring Cost/Aircraft | QTY |
|---|---|---|---|
| Galley | 110,900 | 277,250 | [illegible] |
| Hide-a-bed | 1,109 | 16,635 | 1 |
| TV/VCR Cabinet | 5,545 | 38,815 | 1 |
| VCR | | 12,199 | 1 |
| TV | | 13,308 | 1 |
| Business Class Seats | | 7,763 | [illegible] |
| Triple Business Class Seats | | 16,635 | |
| First Class Seats | | 11,000 | |
| Sleeper Seats | | 12,000 | [illegible] |
| Worktable | 3,327 | 12,199 | 2 |
| Worktable Seats | | 16,635 | 6 |
| Lavatory | | 110,900 | [illegible] |

Select *CAICET / Avionics*

Model Prompt to Enter Quantities in Shaded Areas

Fill out this module as shown below:

| AVIONICS MODULE<br>Select Avionics Hardware | MODEL/DESCRIPTION | COST/<br>UNIT | QTY |
|---|---|---|---|
| **Collision Avoidance System** | | | |
| Ryan Intl Corp | TCAD ATS 700: Panel-mount passive traffic alert system. | 4,975 | |
| BF Goodrich Flt Sys | TCAS 791: TCAS-1 system | 60,000 | |
| Honeywell, Inc | TCZ 910: Includes R/T's and one directional antenna | 106,544 | |
| Bendix/King | CAS 81: TCAS-II system, dual directional antenna | 195,950 | |
| **Global Positioning System** | | | |
| Trimble | Flightmate: 3 channel/No TSO/No IFR/LCD display | 995 | |
| Northstar | PS 600: 6 channel/TSO/No IFR/LED display | 4,995 | 1 |
| II Morrow | NWS 2001D: 8 channel/Pnd TSO/Pnd IFR/LED display | 7,495 | |
| **Flight Management System** | | | |
| II Morrow | 2001 GPS | 3,995 | |
| Internav | GC1200 | 19,000 | |
| Global Wulfsberg Sys | GNS 500A | 63,764 | 1 |
| Honeywell, Inc | FMZ 800 | 106,075 | |
| Litton Aero Products | LTN 92 | 192,540 | |
| **VHF Navigation Receiver** | | | |
| Terra Corp | TN 200D: No TSO | 1,095 | |
| Becker Avionics, Inc | NR-3301: TSO C34c/C40a | 2,450 | 1 |
| S-TEC Corp | VIR 351: TSO C36c/C40a | 4,403 | |
| **Transponder** | | | |
| Bendix/King | KT 76A: TSO C47c Class 1A | 1,420 | |
| Bendix/King | TRS 42: TSO C74c Class 1A | 12,460 | |
| Collins Avionics Gr | TDR 94D: TSO C112 Class 3 | 29,600 | 1 |
| **IFF/TACS/TACAN** | | 25,000 | 1 |
| **Microwave Landing System** | | | |
| Bendix/King | MLS 21 | 24,750 | 1 |
| Honeywell, Inc | MLZ 850 | 28,134 | |
| Canadian Marconi Co | CMA 2000 "Microlander" | 28,800 | |
| **LORAN** | | | |
| II Morrow | Flybuddy 820: Single Receiver/No TSO/No IFR/LCD | 1,195 | |
| Bendix/King | KLN 88: One channel/C60b TSO/IFR/CRT display | 5,975 | |
| Arnav | Arnav 7000: Multi Receiver/TSO/IFR/LED display | 9,995 | 1 |
| **Color Weather Radar** | | | |
| Narco Avionics, Inc | KWX 56: 2 units/18 lbs/3 colors | 12,756 | 1 |
| Bendix/King | RDS 84VP: 2 units/37.27 lbs/4 colors | 43,305 | |
| Honeywell, Inc | Primus 700: 4 units/38 lbs/5 colors | 95,173 | |

Select *CAICET / Timephasing*

WBS elements are timephased by placing the cursor on the spreadsheet row of the element and then choosing *S-Curve* or *By Quantity*. The Timephasing Module should be completed as follows:

| TIMEPHASING MODULE<br>Select Timephasing Method | | FIRST UNIT | METHOD |
|---|---|---|---|
| 1.0 | Aircraft System | 97,025 | Summation |
| 1.1 | Air Vehicle | 79,404 | Summation |
| 1.1.1 | Basic Aircraft | 52,455 | Summation |
| 1.1.1.1 | Airframe | 52,000 | By Qty |
| 1.1.1.2 | Paint | 455 | By Qty |
| 1.1.2 | Interior | 2,406 | Summation |
| 1.1.2.1 | Recurring Interior | 2,285 | By Qty |
| 1.1.2.2 | Non-Recurring Interior | 121 | By Qty |
| 1.1.3 | Avionics | 2,473 | Summation |
| 1.1.3.1 | Recurring Avionics | 473 | By Qty |
| 1.1.3.2 | Non-Recurring Avionics | 2,000 | By Qty |
| 1.1.4 | Communications | 14,384 | Summation |
| 1.1.4.1 | Recurring MCS | 11,405 | By Qty |
| 1.1.4.2 | Non-Recurring MCS | 2,979 | By Qty |
| 1.1.5 | Self-Sufficiency | 2,279 | Summation |
| 1.1.5.1 | Airstairs | 557 | By Qty |
| 1.1.5.2 | Security System | 472 | By Qty |
| 1.1.5.3 | Baggage Loader | 620 | By Qty |
| 1.1.5.4 | Non-Recurring Self-Suff | 630 | By Qty |
| 1.1.6 | Self Defense System | 790 | By Qty |
| 1.1.7 | Auxiliary Power Unit | 1,563 | Summation |
| 1.1.7.1 | Recurring APU | 813 | By Qty |
| 1.1.7.2 | Non-Recurring APU | 750 | By Qty |
| 1.1.8 | Engineering Change Orders | 3,054 | 60/40 S-Curve |
| 1.2 | Sys Eng / Prog Mngt | 4,853 | 55/45 S-Curve |
| 1.3 | System Test & Evaluation | 1,050 | 65/35 S-Curve |
| 1.4 | Training | 349 | 70/30 S-Curve |
| 1.5 | Data | 2,265 | 55/45 S-Curve |
| 1.6 | PSE | 1,163 | 85/15 S-Curve |
| 1.7 | Site Activation | | |
| 1.8 | Initial Spares | 7,940 | 50/50 S-Curve |

When Timephasing is completed you can view the AF Form 1537 by selecting either the Base Year or Then Year button.

Select *CAICET / Output*

By selecting output from the pull down menu, the model will automatically print the following documents: AF Form 1537 in Base Year and Then Year, and the interior, avionics, and timephasing modules. The AF Form 1537's for this example are provided on the following pages.

| WEAPON SYSTEM BUDGET ESTIMATE (Amount in Thousands Dollars) | | WEAPON SYSTEM B767-200 | | CONTRACTOR TBD | | | AS OF DATE 16 August 93 |
|---|---|---|---|---|---|---|---|
| CATEGORY BY1994$ PE: TBD SPAC: TBD | | EQUIP // CFE // GFE | | REPORT CONTROL SYMBOL AFIT/LAA | | | PREPARED BY Capt Bundy |
| FISCAL YEAR DESCRIPTION QUANTITY | | Prior | 1995 2 | 1996 2 | 1997 2 | Total 6 | |
| 1.0 | Aircraft System | | 189,042 | 195,587 | 169,333 | 553,962 | |
| 1.1 | Air Vehicle | | 156,177 | 150,624 | 146,555 | 453,356 | |
| 1.1.1 | Basic Aircraft | | 107,427 | 107,427 | 107,427 | 322,282 | |
| 1.1.1.1 | Airframe | | 106,496 | 106,496 | 106,496 | 319,488 | |
| 1.1.1.2 | Paint | | 931 | 931 | 931 | 2,794 | |
| 1.1.2 | Interior | | 4,804 | 4,680 | 4,680 | 14,165 | |
| 1.1.2.1 | Recurring Interior | | 4,680 | 4,680 | 4,680 | 14,041 | |
| 1.1.2.2 | Non-Recurring Interior | | 124 | | | 124 | |
| 1.1.3 | Avionics | | 3,017 | 969 | 969 | 4,956 | |
| 1.1.3.1 | Recurring Avionics | | 969 | 969 | 969 | 2,908 | |
| 1.1.3.2 | Non-Recurring Avionics | | 2,048 | | | 2,048 | |
| 1.1.4 | Communications | | 26,408 | 23,357 | 23,357 | 73,122 | |
| 1.1.4.1 | Recurring MCS | | 23,357 | 23,357 | 23,357 | 70,072 | |
| 1.1.4.2 | Non-Recurring MCS | | 3,050 | | | 3,050 | |
| ..1.5 | Self Sufficiency | | 4,023 | 3,378 | 3,378 | 10,779 | |
| 1.1.5.1 | Airstairs | | 1,141 | 1,141 | 1,141 | 3,422 | |
| 1.1.5.2 | Security System | | 968 | 968 | 968 | 2,903 | |
| 1.1.5.3 | Baggage Loader | | 1,270 | 1,270 | 1,270 | 3,809 | |
| 1.1.5.4 | Non-Recurring Self-Suff | | 645 | | | 645 | |
| 1.1.6 | Self Defense System | | 1,617 | 1,617 | 1,617 | 4,852 | |
| 1.1.7 | Auxiliary Power Unit | | 2,433 | 1,665 | 1,665 | 5,762 | |
| 1.1.7.1 | Recurring APU | | 1,665 | 1,665 | 1,665 | 4,994 | |
| 1.1.7.2 | Non-Recurring APU | | 768 | | | 768 | |
| 1.1.8 | Engineering Change Orders | | 6,447 | 7,529 | 3,460 | 17,437 | |
| 1.2 | Sys Eng / Prog Mngt | | 8,648 | 12,740 | 6,319 | 27,707 | |
| 1.3 | System Test & Evaluation | | 2,591 | 2,384 | 1,020 | 5,995 | |
| 1.4 | Training | | 996 | 713 | 285 | 1,995 | |
| 1.5 | Data | | 4,037 | 5,946 | 2,949 | 12,932 | |
| 1.6 | PSE | | 4,840 | 1,351 | 451 | 6,643 | |
| 1.7 | Site Activation | | | | | | |
| 1.8 | Initial Spares | | 11,754 | 21,828 | 11,754 | 45,336 | |

| WEAPON SYSTEM BUDGET ESTIMATE (Amount In Thousands Dollars) | | WEAPON SYSTEM B767-200 | | CONTRACTOR TBD | | | AS OF DATE 18 August 93 | |
|---|---|---|---|---|---|---|---|---|
| CATEGORY TY$ PE: TBD BPAC: TBD | | EQUIP // CFE //GFE | | REPORT CONTROL SYMBOL AFIT/LAA | | | PREPARED BY Capt Bundy | |
| FISCAL YEAR DESCRIPTION QUANTITY OF AIRCRAFT | | Prior | 1995 2 | 1996 2 | 1997 2 | Total 6 | | |
| 1.0 | Aircraft System | | 203,442 | 215,069 | 190,334 | 608,845 | | |
| 1.1 | Air Vehicle | | 168,074 | 165,628 | 164,731 | 498,432 | | |
| 1.1.1 | Basic Aircraft | | 115,610 | 118,128 | 120,751 | 354,490 | | |
| 1.1.1.1 | Airframe | | 114,608 | 117,104 | 119,704 | 351,416 | | |
| 1.1.1.2 | Paint | | 1,002 | 1,024 | 1,047 | 3,074 | | |
| 1.1.2 | Interior | | 5,170 | 5,147 | 5,261 | 15,578 | | |
| 1.1.2.1 | Recurring Interior | | 5,037 | 5,147 | 5,261 | 15,445 | | |
| 1.1.2.2 | Non-Recurring Interior | | 133 | | | 133 | | |
| 1.1.3 | Avionics | | 3,247 | 1,066 | 1,090 | 5,403 | | |
| 1.1.3.1 | Recurring Avionics | | 1,043 | 1,066 | 1,090 | 3,199 | | |
| 1.1.3.2 | Non-Recurring Avionics | | 2,204 | | | 2,204 | | |
| 1.1.4 | Communications | | 28,419 | 25,684 | 26,254 | 80,357 | | |
| 1.1.4.1 | Recurring MCS | | 25,136 | 25,684 | 26,254 | 77,074 | | |
| 1.1.4.2 | Non-Recurring MCS | | 3,283 | | | 3,283 | | |
| 1.1.5 | Self-Sufficiency | | 4,330 | 3,715 | 3,797 | 11,841 | | |
| 1.1.5.1 | Airstairs | | 1,228 | 1,284 | 1,282 | 3,794 | | |
| 1.1.5.2 | Security System | | 1,041 | 1,064 | 1,088 | 3,193 | | |
| 1.1.5.3 | Baggage Loader | | 1,366 | 1,398 | 1,427 | 4,190 | | |
| 1.1.5.4 | Non-Recurring Self-Suff | | 694 | | | 694 | | |
| 1.1.6 | Self Defense System | | 1,741 | 1,779 | 1,818 | 5,337 | | |
| 1.1.7 | Auxiliary Power Unit | | 2,618 | 1,831 | 1,871 | 6,320 | | |
| 1.1.7.1 | Recurring APU | | 1,792 | 1,831 | 1,871 | 5,494 | | |
| 1.1.7.2 | Non-Recurring APU | | 827 | | | 827 | | |
| 1.1.8 | Engineering Change Orders | | 6,939 | 8,279 | 3,889 | 19,107 | | |
| 1.2 | Sys Eng / Prog Mngt | | 9,307 | 14,009 | 7,102 | 30,418 | | |
| 1.3 | System Test & Evaluation | | 2,788 | 2,622 | 1,147 | 6,556 | | |
| 1.4 | Training | | 1,072 | 784 | 321 | 2,177 | | |
| 1.5 | Data | | 4,344 | 6,538 | 3,315 | 14,197 | | |
| 1.6 | PSE | | 5,209 | 1,486 | 507 | 7,202 | | |
| 1.7 | Site Activation | | | | | | | |
| 1.8 | Initial Spares | | 12,649 | 24,003 | 13,211 | 49,863 | | |

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# Vita

C. Grant McVicker III was born on 22 January 1963 in Pittsburgh, Pennsylvania. He attended West Virginia University, graduating with a Bachelor of Science degree in Corporate Finance in December 1985. He was commissioned in the Air Force through the Air Force Reserve Officer's Training Corps in December 1985. He entered active duty in February 1986 at Vandenberg AFB, California and attended Initial Qualification Training to become a Minuteman ICBM Combat Crew Commander. Upon completion of training, he was assigned to Malmstrom AFB, Montana where he served as a Missile Launch Officer. While serving in this capacity, he completed a Master of Business Administration degree from the University of Montana in March 1989. In August 1990, he was assigned to the Aircraft System Program Office, Aeronautical Systems Division, Wright-Patterson AFB, Ohio, as the Financial Manager of the Transports Aircraft. In July 1991, he was assigned as the Executive Transports Financial Manager to provide cost estimates for aircraft alternatives for the VC-137 Replacement Program. He held this position until he was selected to attend Squadron Officer's School in February 1992. Upon graduation, Capt McVicker entered the School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB.

Permanent Address: 1428 Washington Ave
Parkersburg WV 26101

## Vita

Captain Michael T. Roche was born on 12 April 1967 in Syracuse, New York. He graduated from Christian Brothers Academy in Syracuse, earned a Bachelor of Science Degree in Mathematics and Criminal Justice from the University of Dayton, and received his commission as an Air Force officer as a Distinguished Graduate of the Reserve Officer Training Corps. In his first tour of duty, he served as the Financial Manager for the F-111 Avionics Modernization Program, F-111 Digital Flight Control System Program, YA-7F Prototype Program, and A-10 Technology Demonstrator Program, all managed in the Aircraft System Program Office at Wright-Patterson AFB, Ohio. There he was responsible for financial planning, presenting, and executing program budgets totalling in excess of $350 million. During this tour, he served as the Chairman of the Aeronautical Systems Center Comptroller Total Quality Team. He was then chosen to serve as the Cost Estimator for the expected $1.6 billion VC-137 Replacement (VC-X) Program, which is also managed in the Aircraft System Program Office. In May 1992, he was assigned to the School of Systems and Logistics, Air Force Institute of Technology.

Permanent Address: 65 North Vernon Ave
Newark OH 43055

# REPORT DOCUMENTATION PAGE

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**13. ABSTRACT** *(Maximum 200 words)*
The purpose of this research was to develop a cost estimating model which would allow cost estimators the ability to quickly and accurately estimate the acquisition of Air Force Special Air Mission fleet aircraft. The literature review revealed studies, government contracts, and trade publications which served as source data. This information was supplemented by interviews with acquisition specialists and contractors and incorporated into a database. Several estimating techniques were created and used to estimate the various cost elements. The Commercial Aircraft Integrated Cost Estimating Tool (CAICET) model was then developed to incorporate the estimating techniques with the database. This was accomplished by integrating dialog boxes to access the information and estimate the program acquisition. The CAICET model provides the analyst with the ability to estimate an acquisition program based on a few specific parameters concerning the missionization of the aircraft. These parameters include interior configuration, avionics, mission communications, and self-sufficiency items. Once this information is input, the CAICET model provides the analyst with a real-time estimate in standard AF Form 1537 format.

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   a. Highly Significant  b. Significant  c. Slightly Significant  d. Of No Significance

5. Comments

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